

QoS for Real Time Applications over Next Generation Data Networks

Project Status Report: Part 1
June 2, 2000

<http://www.engr.udayton.edu/faculty/matiquzz/Pres/QoS.pdf>

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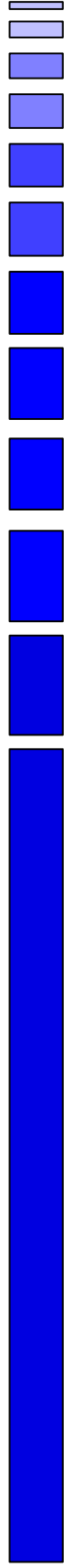
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Outline of Talk



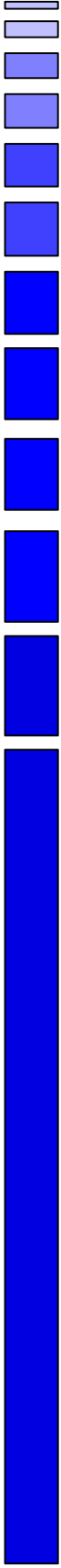
- Present state of the Internet.
- QoS approaches to future data networks.
- Research Issues.
- Progress to date:
 - Task 1: DS over ATM
 - Task 2: IS over DS
 - Task 3: ATN
 - Task 4: Satellite networks
 - Task 5: MPLS
- Conclusions.

Current Internet



- TCP/IP glues together all the computers in the Internet.
- TCP/IP was designed for terrestrial networks.
- TCP/IP does not
 - offer QoS to real time applications, or
 - perform well in long delay bandwidth networks.

Efforts to provide QoS in Internet



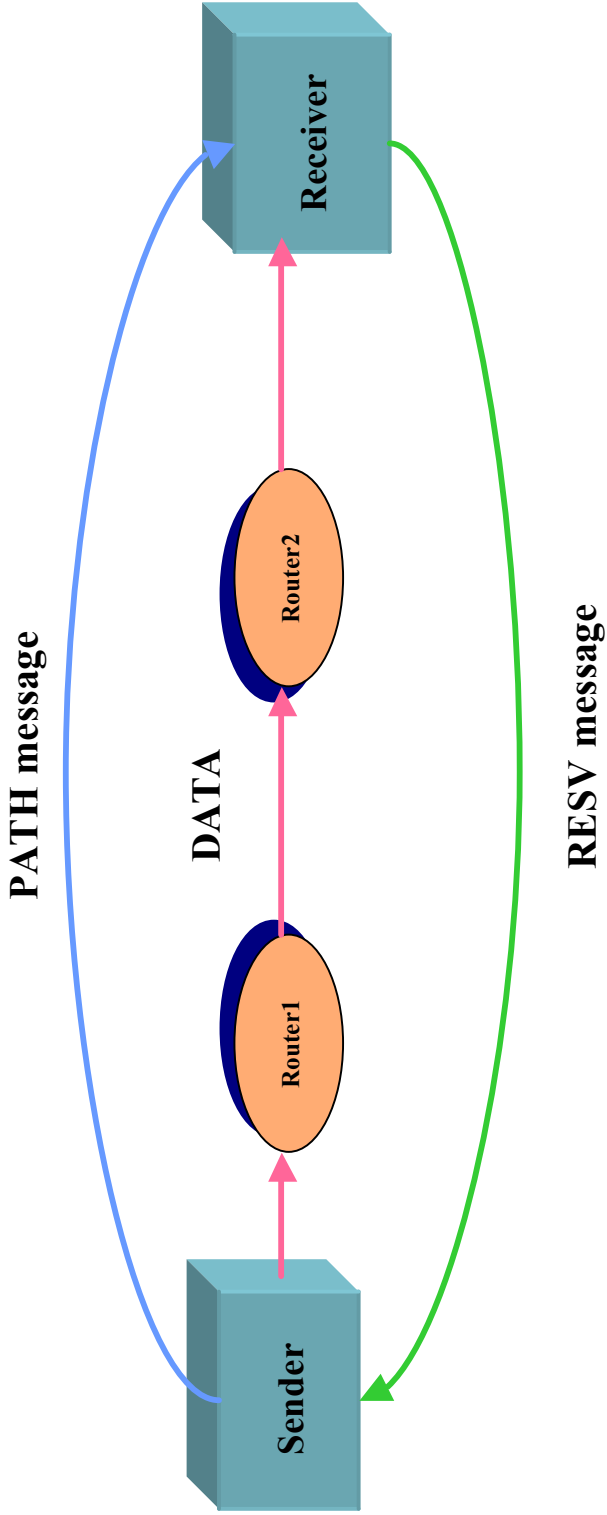
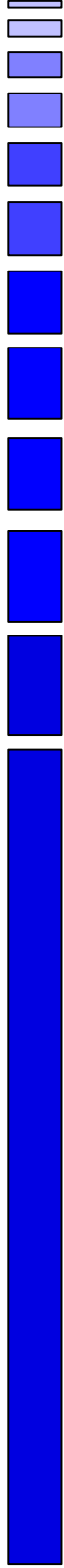
- Integrated Services (IS)
- Differentiated Services (DiffServ)
- Explicit Congestion Notification (ECN)
- Multiprotocol Label Switching (MPLS)
- Asynchronous Transfer Mode (ATM)

Integrated Services



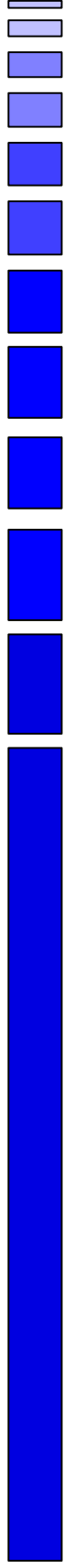
- RSVP to reserve resources during connection setup.
- End-to-end QoS guarantees.
- A router has to keep information about all connections passing through the router.
- Gives rise to scalability problem in the core routers.

RSVP Signaling



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RSVP Signaling



- Reserves a portion of link bandwidth in each router
- The sender sends a PATH message with resource requirements for a flow.
- Receiver responds with a RESV message
- Each router processes the RESV to reserve the required resources requested by the sender.
- Routers can modify the QoS parameters of the RESV message if enough resources are not available to meet the requirements.
- Each router in the entire path confirms the end-to-end reservation for the flow.

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IS Service Classes



■ Guaranteed Load Service

- Low end-to-end delay, Jitter, Loss.
- Highest priority service.

■ Controlled Load Service

- Network should forward the packets with queuing delay not greater than that caused by the traffic's own burstiness (RFC 2474).
- Performance similar to that of an unloaded network.
- Traffic specifications from the Tspec.

■ Best Effort

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Differentiated Services



- Similar traffic are grouped into classes.
- Resources reserved for classes.
- QoS provided to classes.
 - QoS to individual connections is an open research issue.
- QoS maintained by:
 - Classification
 - Traffic policing
 - Metering, dropping, tagging
 - Traffic shaping
- Per Hop Behavior (PHB)
 - Specifies QoS received by packets i.e. how packets are treated by the routers.

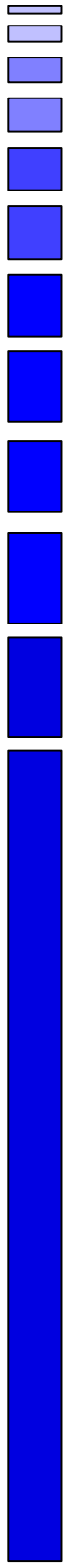
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Asynchronous Transfer Mode



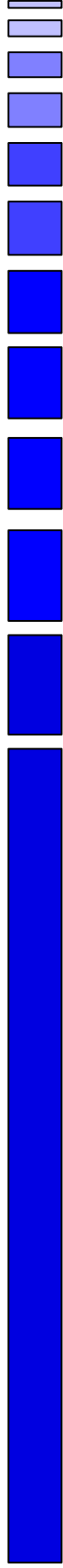
- Strong QoS guarantees; suitable for real time applications.
- High cost prohibits use at the edge network or to the desktop.
- Currently used at the core of the Internet.

Next Generation Internet

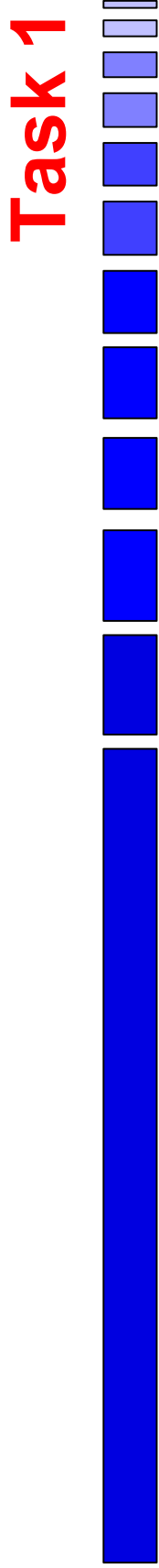


- Routers at the edge network will not need to carry too many connections
 - IS can be used at the edge network.
- Core network needs to carry lot of connections.
 - Combination of DS, ATM and MPLS at the core.
- Satellite/Wireless links
 - Remote connectivity and mobility.

Research Issues



- Service mapping between networks.
- Loss and delay guarantees.
- Interoperability among edge and core technologies.
- Interoperability with Aeronautical Telecommunications Network (ATN).
- Operation in satellite environment having high delay and loss.



Prioritized Early Packet Discard

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Asynchronous Transfer Mode (ATM)



■ Service Classes

- Constant Bits Rate (CBR)
- Available Bit Rate (ABR)
- Unspecified Bit Rate (UBR)

■ CLP in cell header

- Determines loss priority of packets

Differentiated Services



■ Service Classes

- Premium Service: emulates leased line
- Assured Service
- Best Effort Service

■ Various levels of drop precedence.

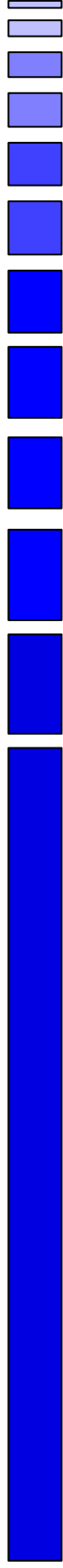
- Need to be mapped to ATM when running DS over ATM.
- Could be possible mapped to the CLP bit of ATM cell header.

DS over ATM



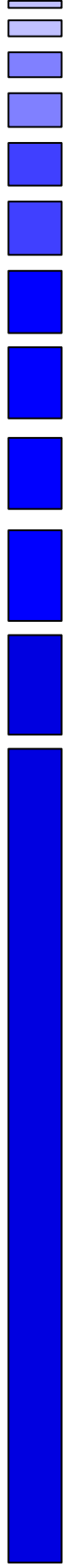
- Possible Service Mappings
 - Premium Service → ATM CBR service.
 - Assured Service → ATM UBR service with CLP=0
 - Best Effort → ATM UBR service with CLP=1
- DS packets are broken down into cells at the DS-ATM gateway
 - Drop precedence mapped to CLP bit
- Buffer Management at ATM switches
 - Partial Packet Discard (PPD)
 - Early Packet Discard (EPD)

Prioritized EPD

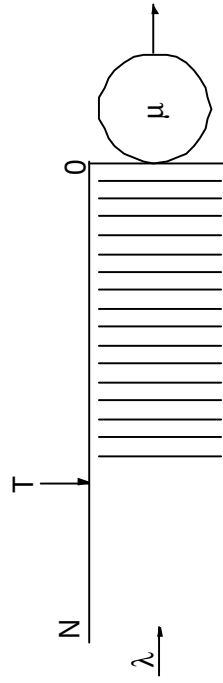


- DS service classes can use the CLP bit of ATM cell header to provide service differentiation.
- EPD does not consider the priority of cells.
- Prioritized EPD can be used to provide service discrimination.
- Two thresholds are used to drop cells depending on the CLP bit.

Buffer Management Schemes

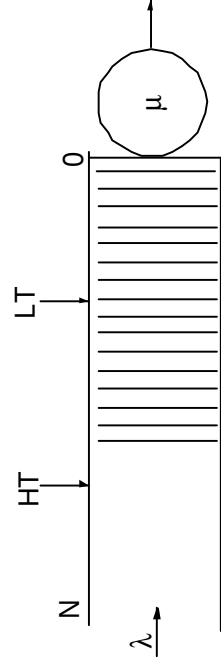


■ EPD



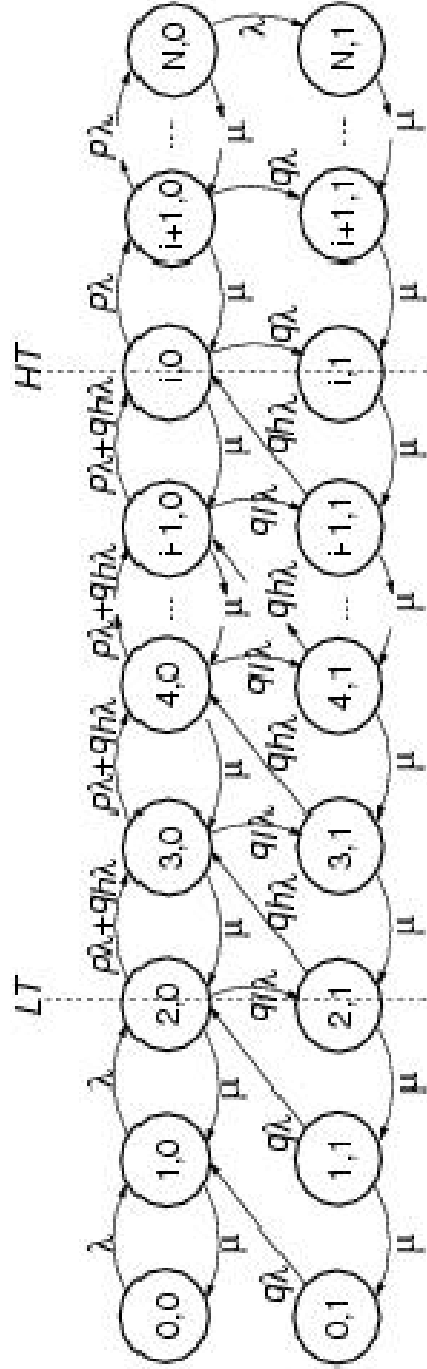
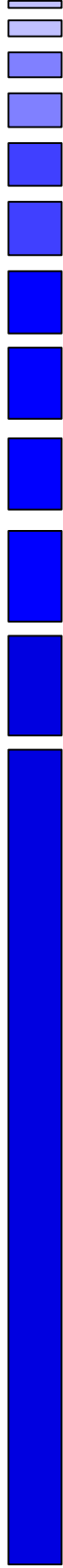
- $QL < T$
Accept all packets.
- $T \leq QL < N$
Discard all new incoming packets.
- $QL \geq N$
Discard all.

■ PEPD



- $QL < LT$
Accept all packets.
- $LT \leq QL < HT$
Discard all new low priority packets.
- $HT \leq QL < N$
Discard all new packets
- $QL \geq N$
Discard all packets

Steady State Diagram



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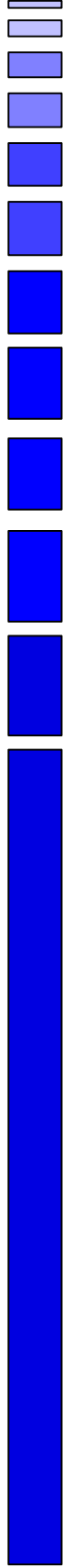
Steady State Equations



$$\begin{aligned}
 l P_{0,0} &= m P_{1,0} \\
 q l P_{0,1} &= m P_{1,1} \\
 (l + m) P_{i,0} &= l P_{i-1,0} + m P_{i+1,0} + q l P_{i-1,1} & 1 \leq i \leq LT \\
 (l + m) P_{i,0} &= (l p + q h l) P_{i-1,0} + m P_{i+1,0} + q h l P_{i-1,1} & LT < i \leq HT \\
 (l + m) P_{i,0} &= p l P_{i-1,0} + m P_{i+1,0} & HT < i < N \\
 (l + m) P_{N,0} &= p l P_{N-1,0} \\
 m P_{N,1} &= l P_{N,0} \\
 m P_{i,1} &= q l P_{i,0} + m P_{i+1,1} & HT \leq i < N \\
 (m + q h l) P_{i,1} &= q l (1 - h) P_{i,0} + m P_{i+1,1} & LT \leq i < HT \\
 (m + q l) P_{i,1} &= m P_{i+1,1} & 0 < i < LT \\
 \sum_{i=0}^N (P_{i,0} + P_{i,1}) &= 1
 \end{aligned}$$

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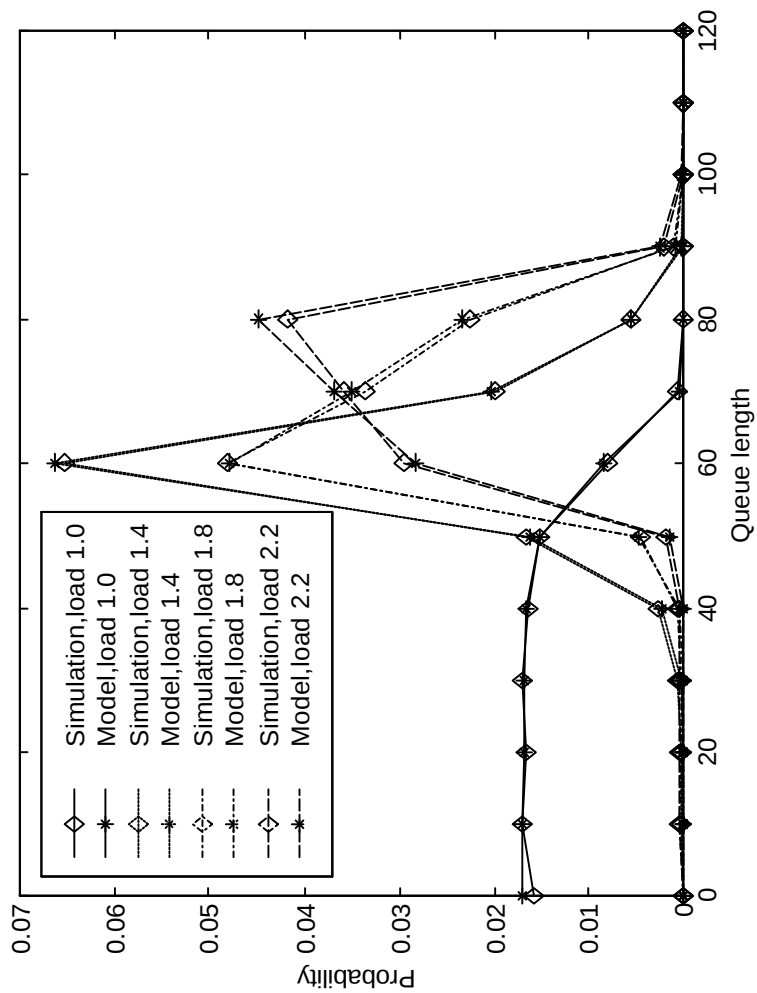
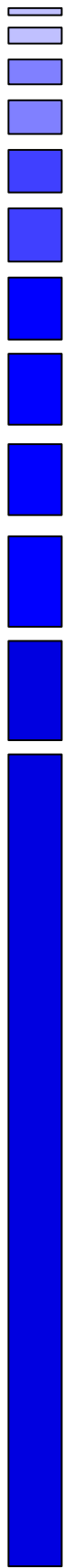
Goodput



$$G_h = \frac{\sum_{n=1}^{\infty} nP(W=n, V=1, U=1)}{\sum_{n=1}^{\infty} nP(W=n, U=1)}$$

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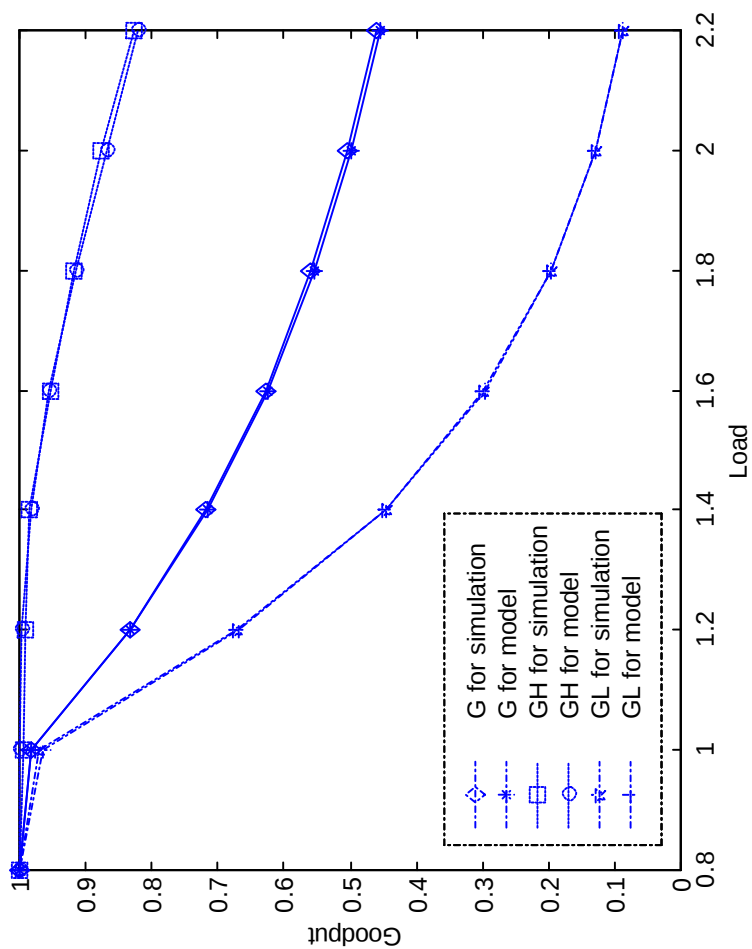
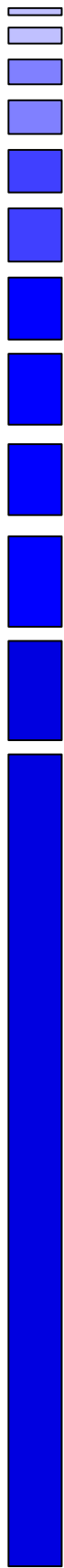
Queue Occupancy



Simulation: $N=120$, $LT=60$, $HT=80$, $h=0.5$, $q=1/6$.

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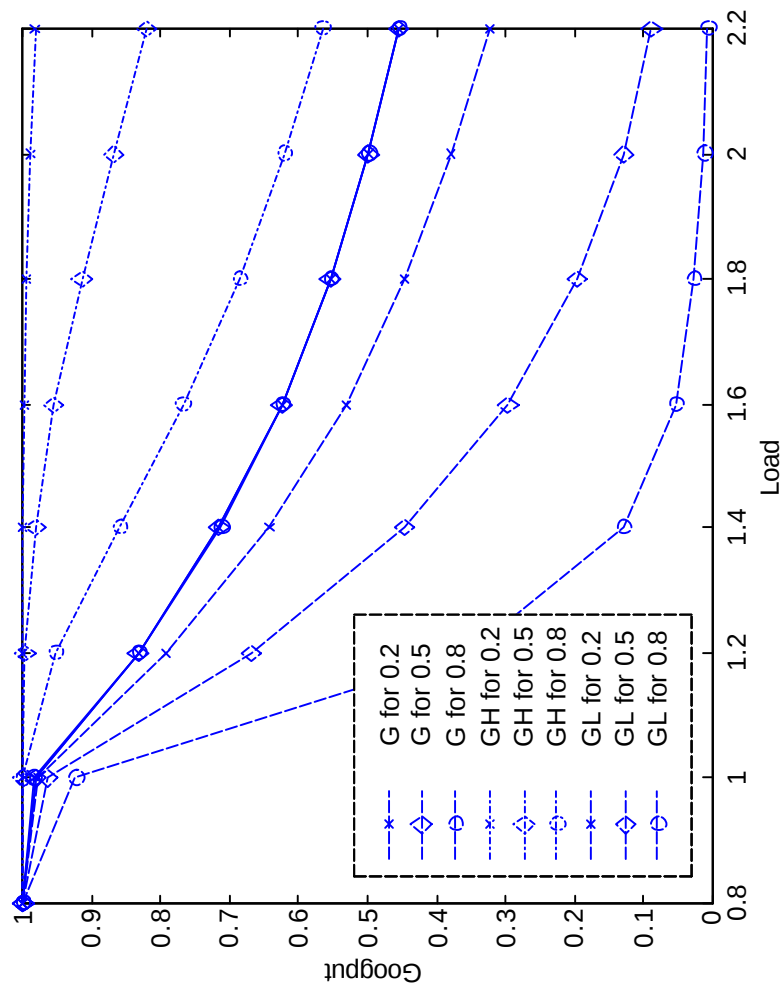
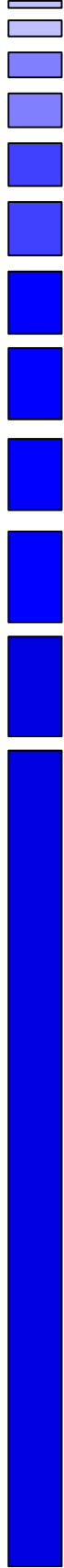
Goodput versus load for $h=0.5$



Simulation: $N=120$, $LT=60$, $HT=80$, $q=1/6$.

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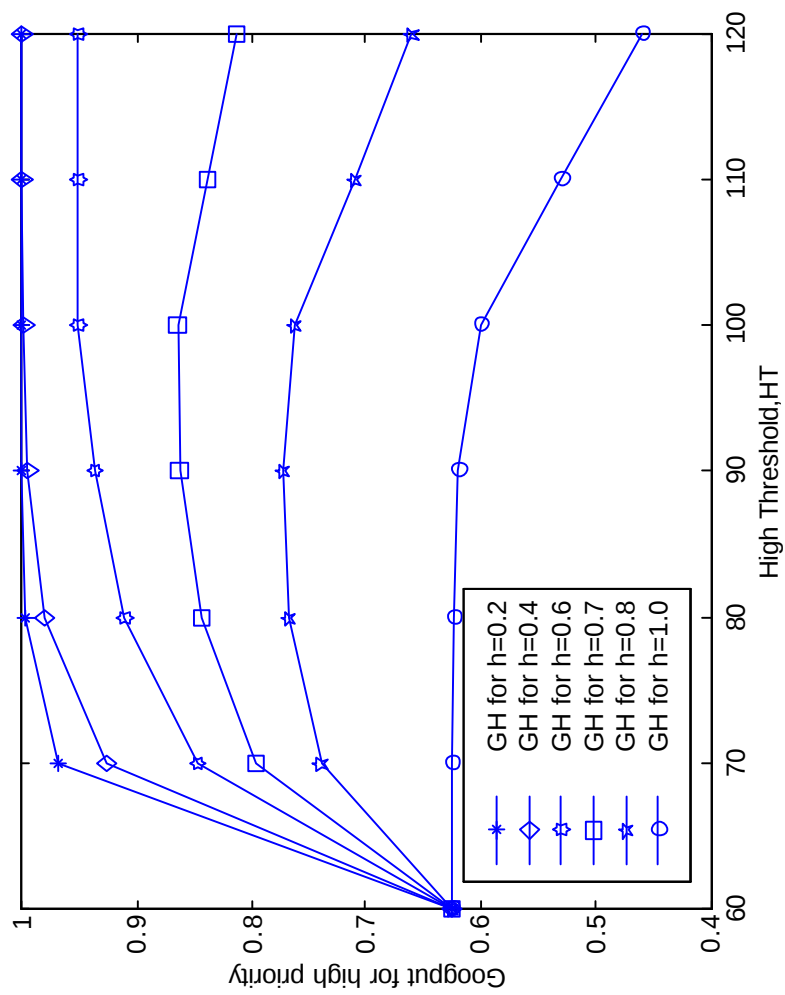
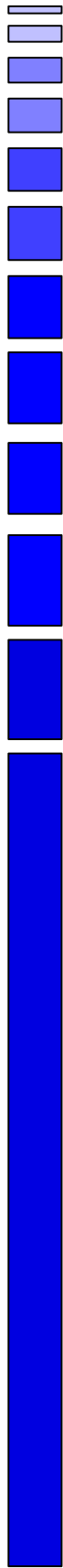
Goodput versus load for $h=0.2, 0.5, 0.8$



Simulation: $N=120, LT=60, HT=80, q=1/6$.

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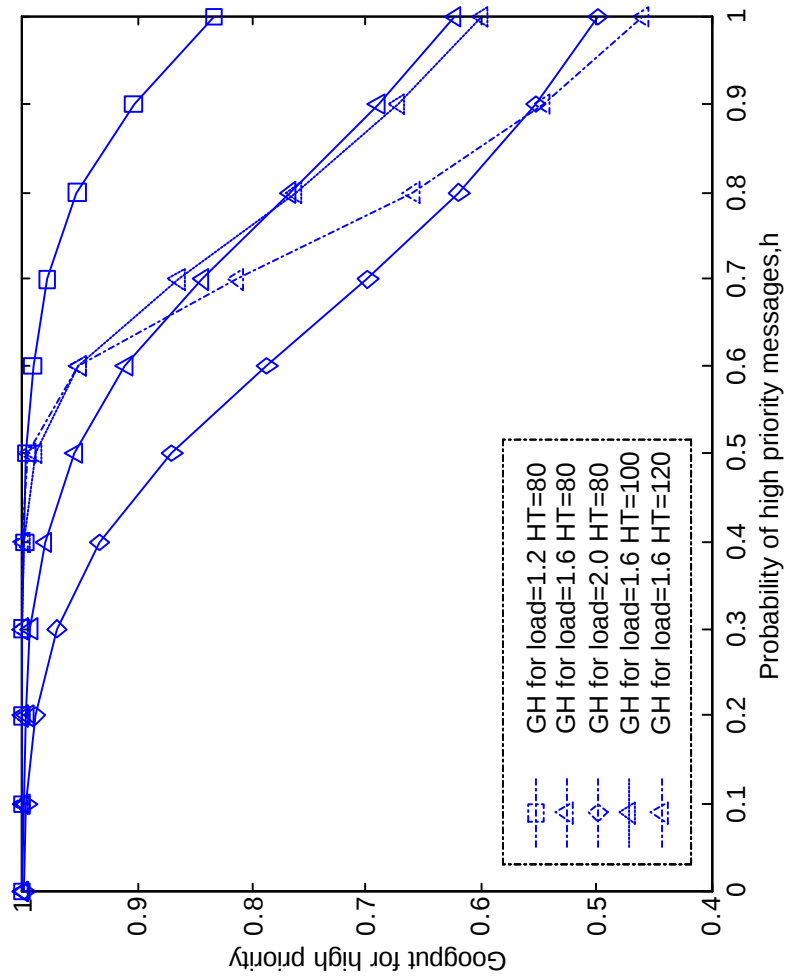
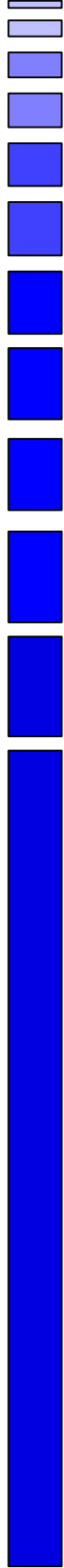
Goodput for high priority vs. HT



Simulation: $LT=60, q=1/6$

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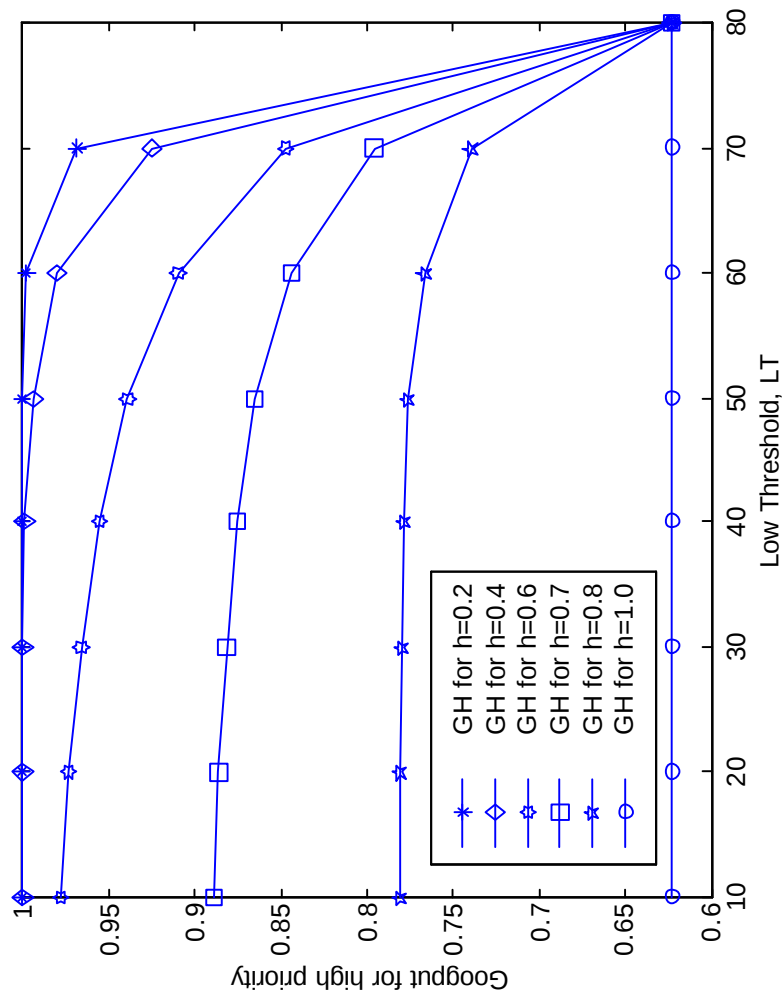
Goodput of high priority vs. h



Simulation: $LT=60$

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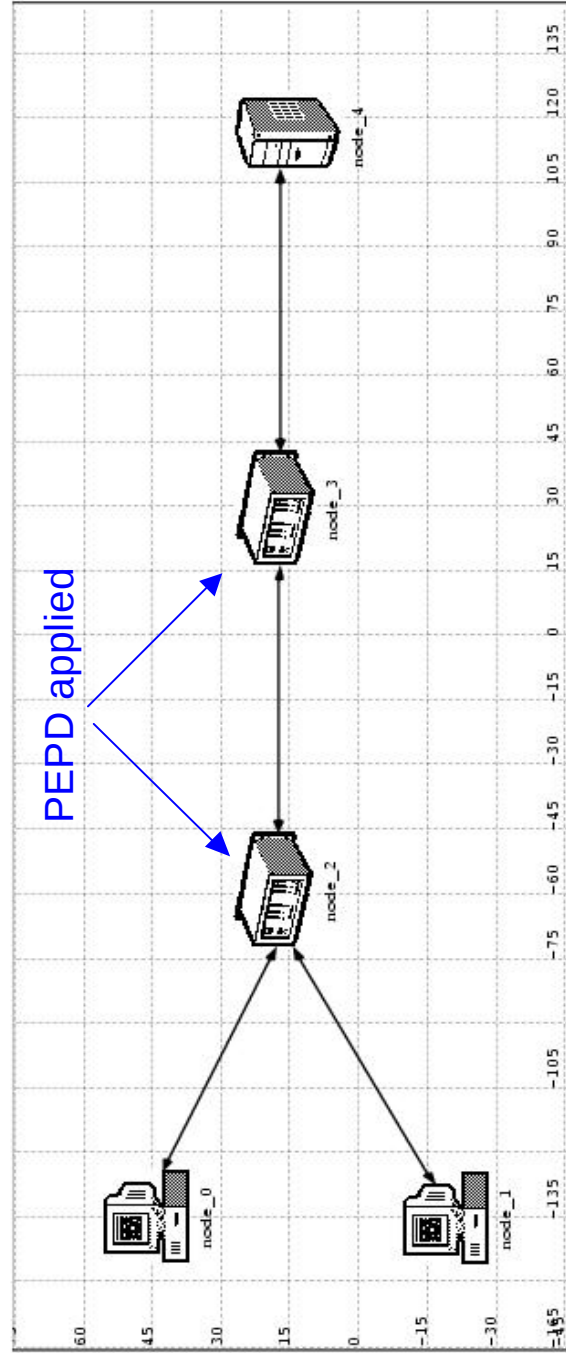
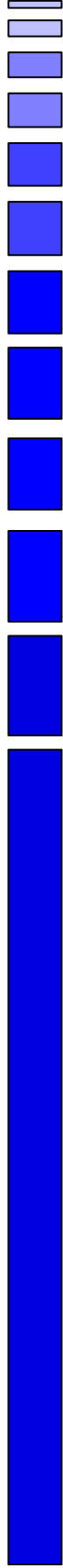
Goodput for high priority versus LT



Simulation: $N=120$, $HT=80$, load=1.6, $q=1/6$.

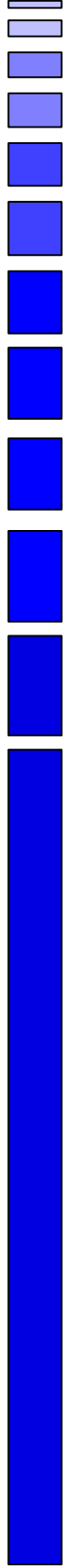
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OPNET Simulation Configuration

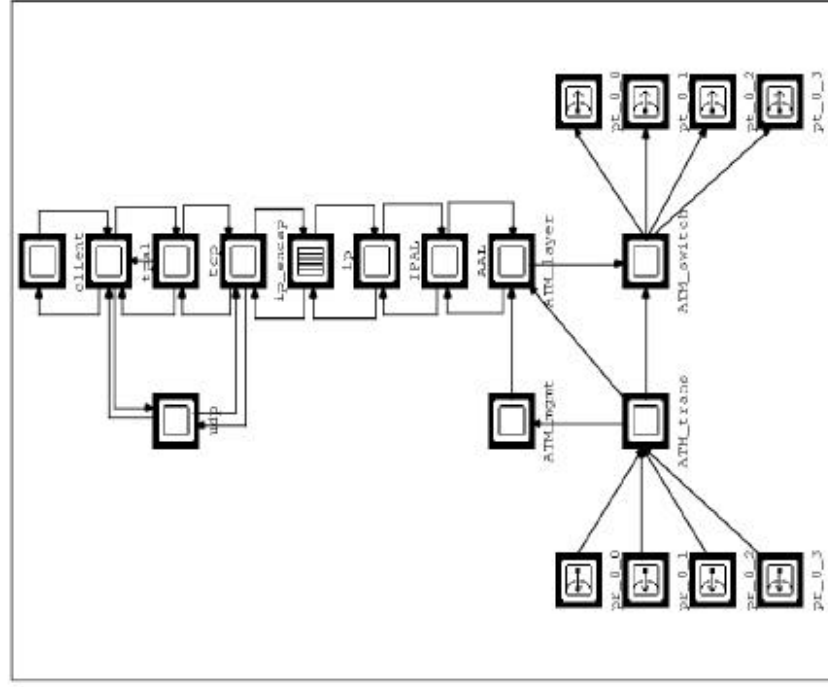


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DS-ATM Protocol Stack

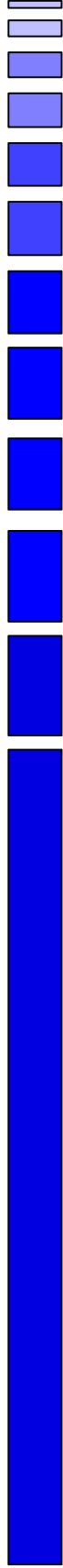


- AAL Layer marks the End of Packet.
- ATM_layer changes the CLP bit depending on the packet of the DS service.

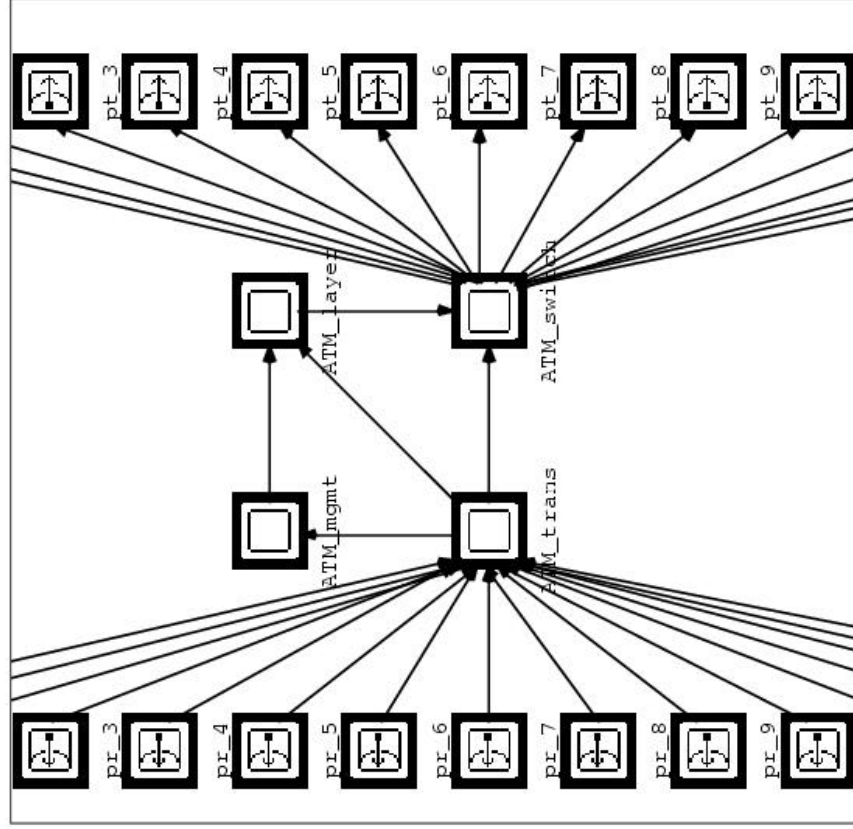


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ATM Switch Node



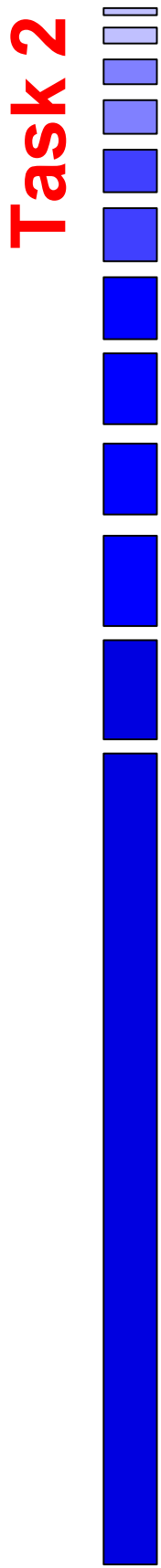
- Support service differentiation in the ATM switch buffer.
- Change the buffer management scheme in the ATM_switch process to Prioritized EPD.



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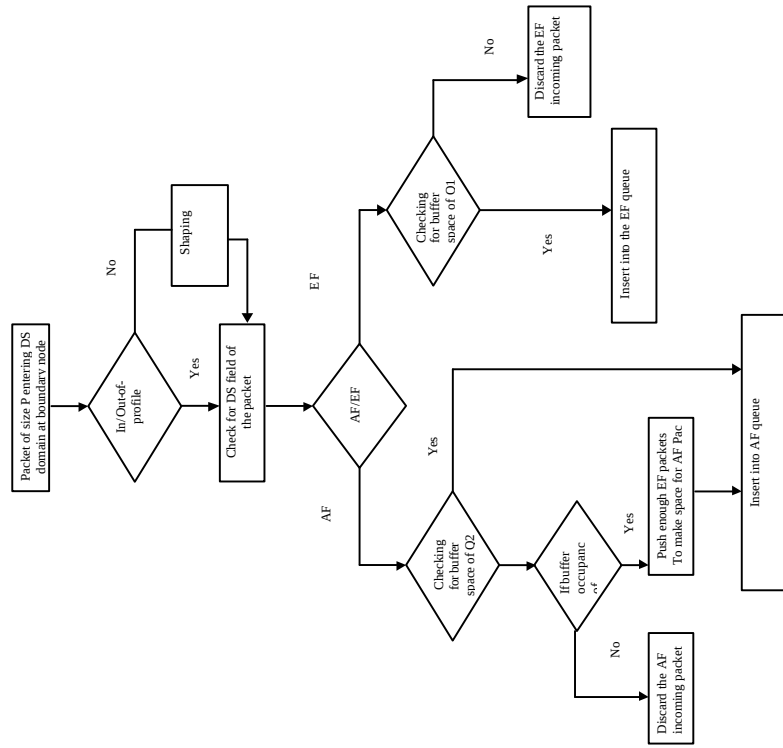
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Mapping of IS over DS

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Traffic entering DS domain



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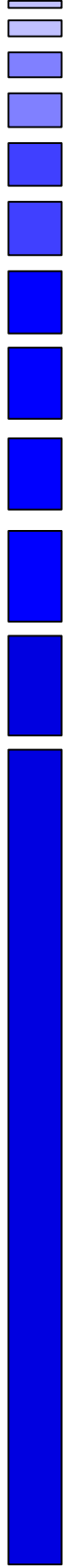
Differentiated Services



- **Classification:** Based on IP header field classifies into BA to receive particular per hop behavior (PHB)
- **Metering:** Measuring the traffic against token bucket to check for resource consumption
- **Shaping:** Treatment of out-of-profile traffic by placing it in a buffer.
- **Dropping:** Non-conformant traffic can be dropped for congestion avoidance
- **Admission Control:** Limiting the amount of traffic according to the resources in the DS domain.
 - **Implicit Admission Control:** Performed at each router
 - **Explicit Admission Control :** Dynamic resource allocation by a centralized bandwidth broker

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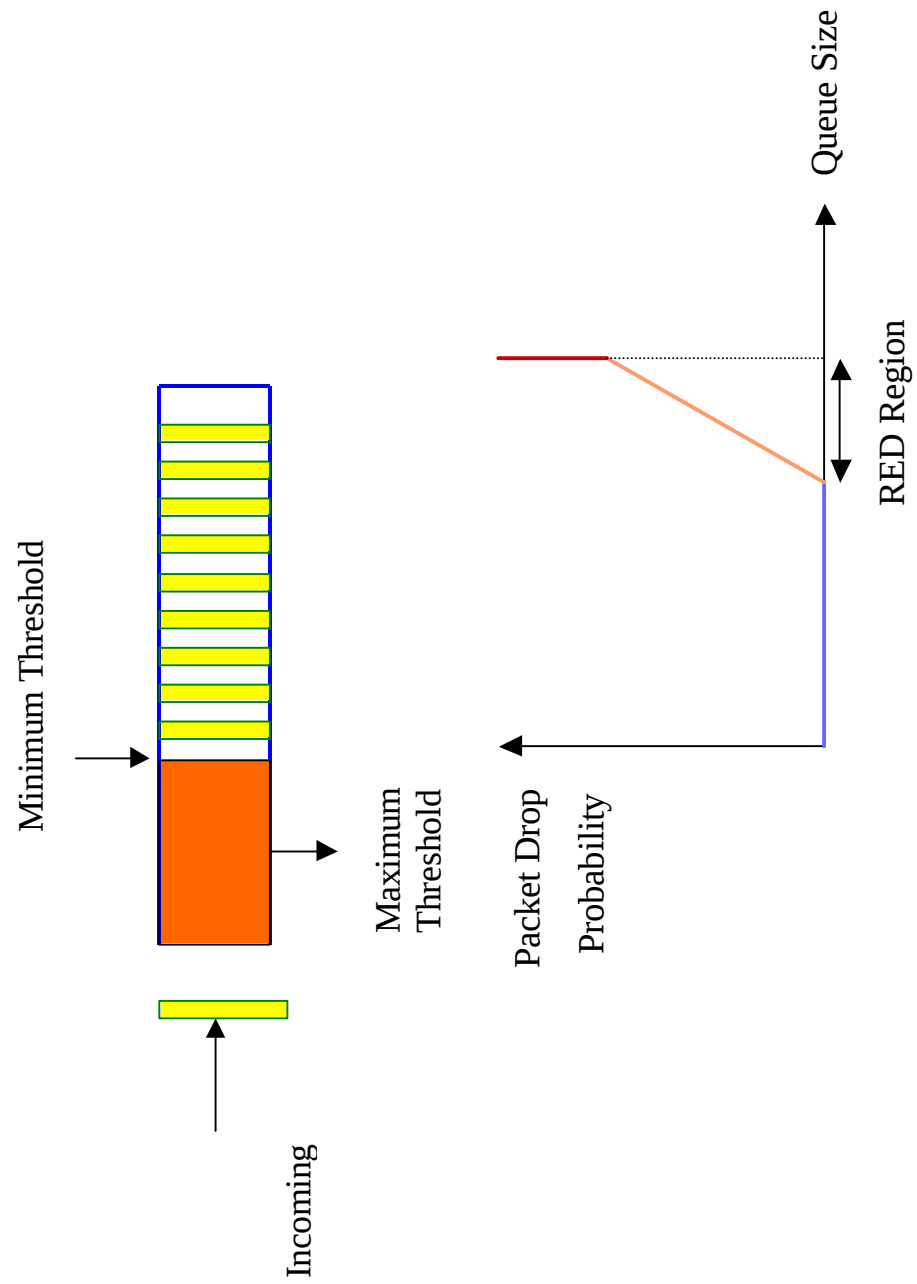
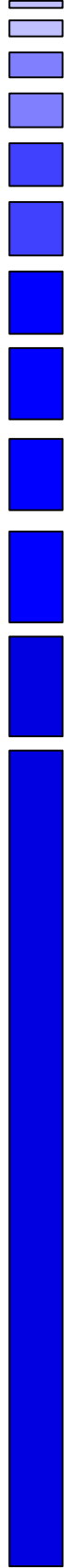
Various PHB's



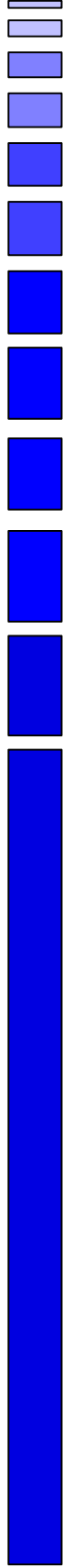
- Expedited Forwarding(EF PHB)
- Assured Forwarding (AF PHB)
- Best Effort (Default)

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Queue Implementation (RED)



QoS Specifications



- Bandwidth:
- Latency:
- Jitter:
- Loss:

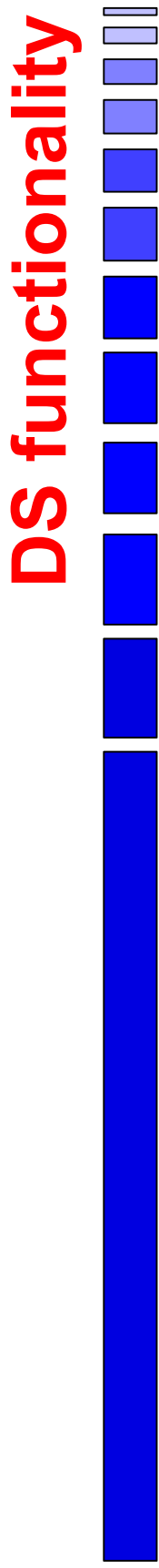
Service Mapping from IS-DS



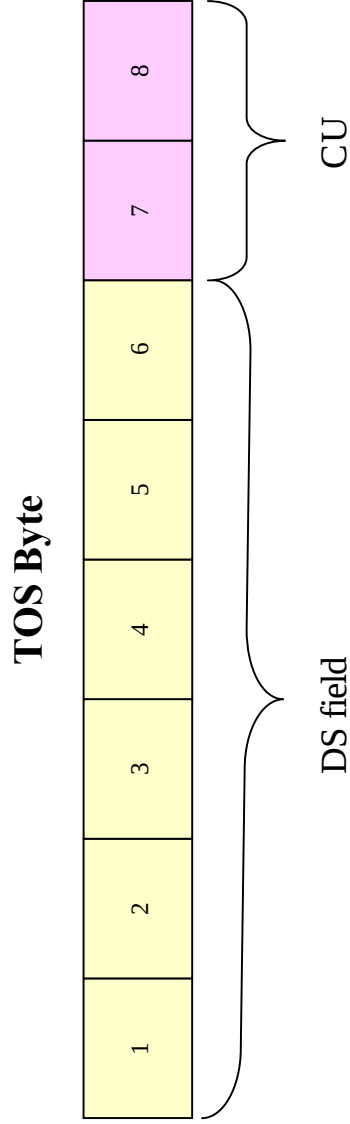
- Provide different levels of service differentiation.
- Provide QoS to multimedia and multicast applications.
- Scalability in terms of resource allocation.
- There is no over head due to per flow state maintenance at each router.
- Forwarding at each router according to the DSCP code.
- PHB's along the path provide a scheduling result approximating the QoS requirements and results in IS

Integrated Service	Differentiated Service
Guaranteed Load	Expedite Forwarding
Controlled Load	Assured Forwarding
Best effort	Default best effort

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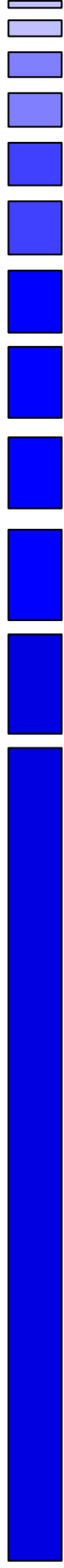


- Per Hop behavior (PHB)
- Behavior Aggregate (BA)
- Differentiated Services Code Point (DSCP)



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Guaranteed load - EF PHB



- Guaranteed traffic performance can be met effectively using the EF PHB with proper policing and shaping functions.
- Shaping Delay
- Queuing Delay
- Packets in the Scheduler

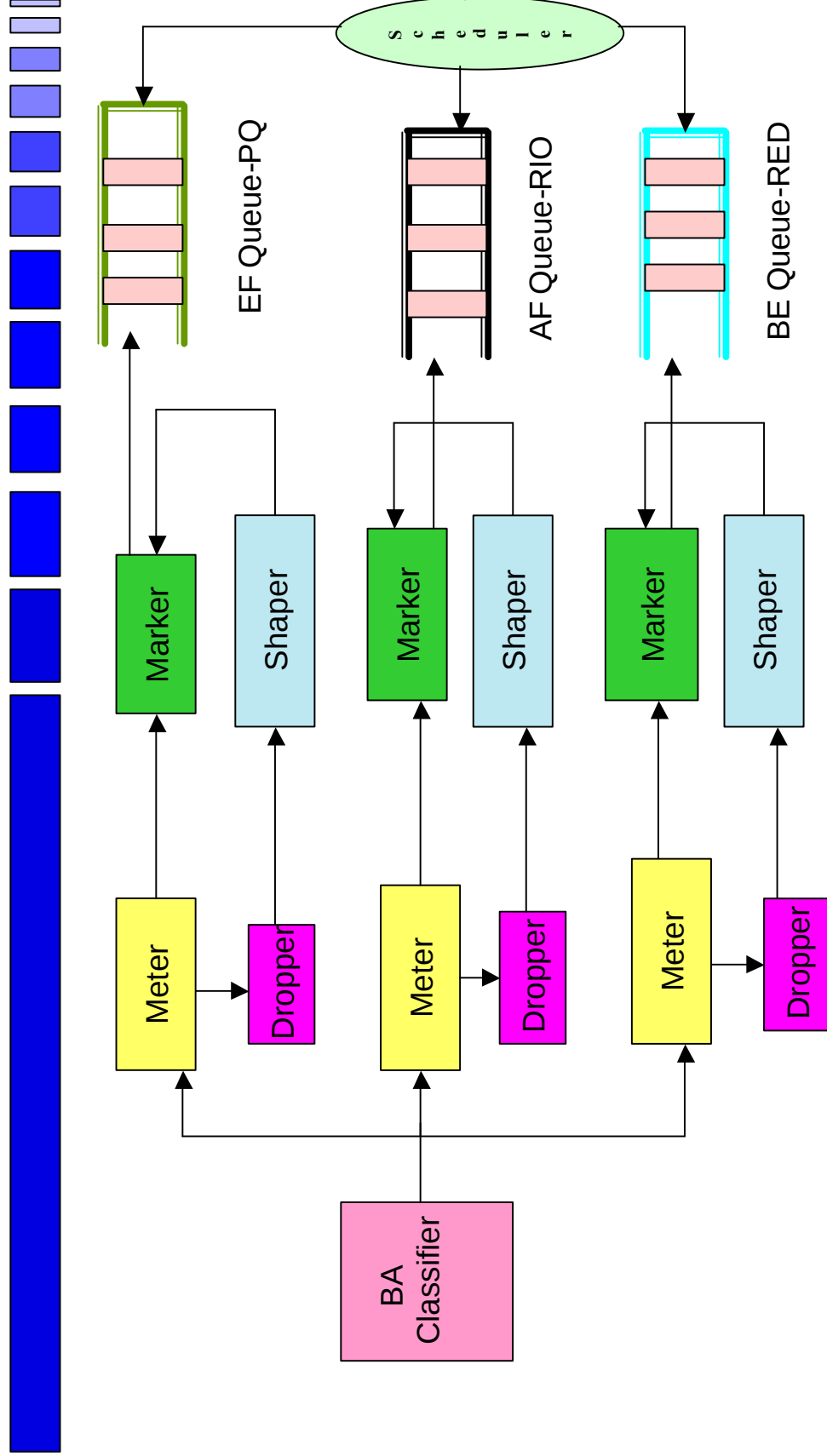
Controlled Load - AF PHB



- Classified into delay classes based on the B/R ratio of Tspec for each delay class; Aggregate Tspec is constructed for all the admitted traffic.
- For each delay class, police the traffic against a token bucket derived above.
- Size of the queue is set to limit the queuing delay of AF requirement.
- RIO dropping parameters are set according to the drop precedence of the AF class.
- AF instance service rate is set to bandwidth sufficient enough to meet the delay and loss requirements of the CL traffic.
- Bandwidth distributed between AF and BE to prevent the BF from starvation.
- Scheduling done with WFQ (Weighted Fair Queuing) or WRR (Weighted Round Robin)

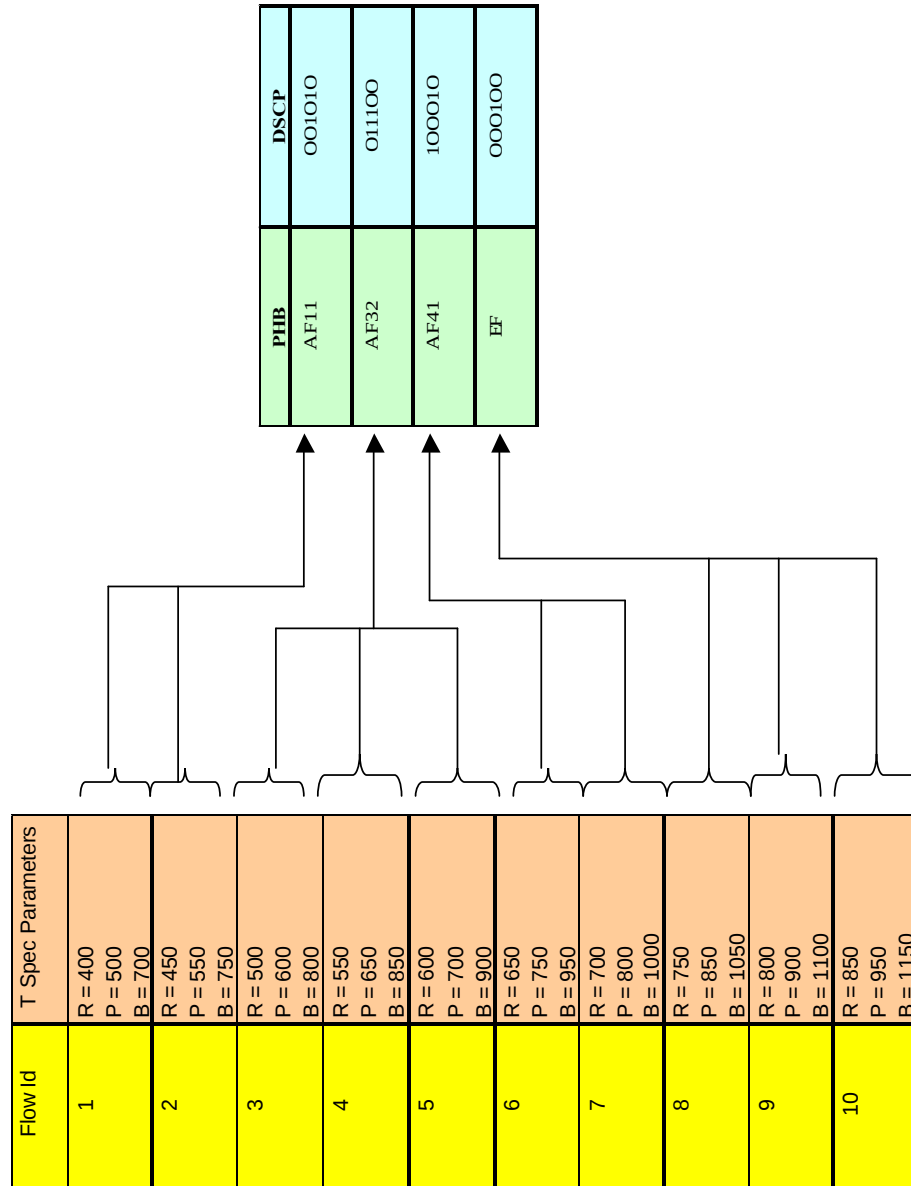
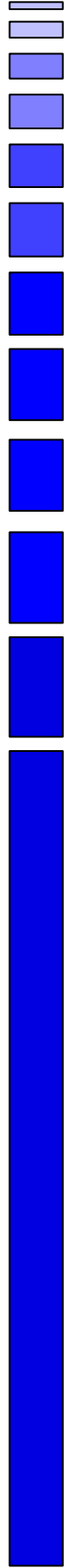
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Traffic Conditioning at DS Boundary



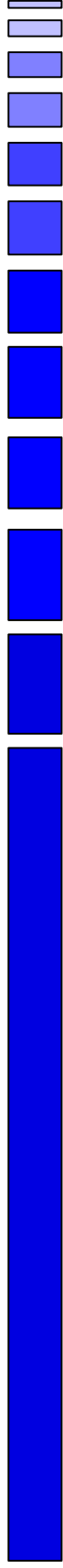
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Mapping Table for IS-to-DS



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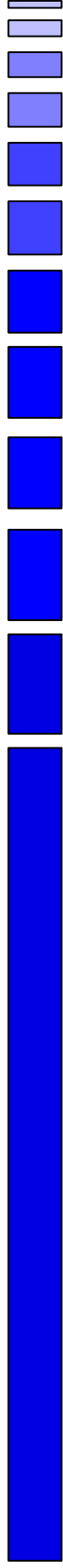
Mapping of IS to DS



- Tspec parameters indicating resource reservation taken from RSVP signaling.
- Table entry contains Tspec parameters, flow IDs, PHB groups and DSCP values.
- Measures actual traffic flow rate against a token bucket according to the initial stored table entry.
- If the traffic is in-profile with the requested reservation, it classifies the packet and marks it with the available DSCP, which can approximately assure the requested QoS.
- The out-of profile traffic is stored in a buffer and shaped to be in conformance with the requested traffic profile.

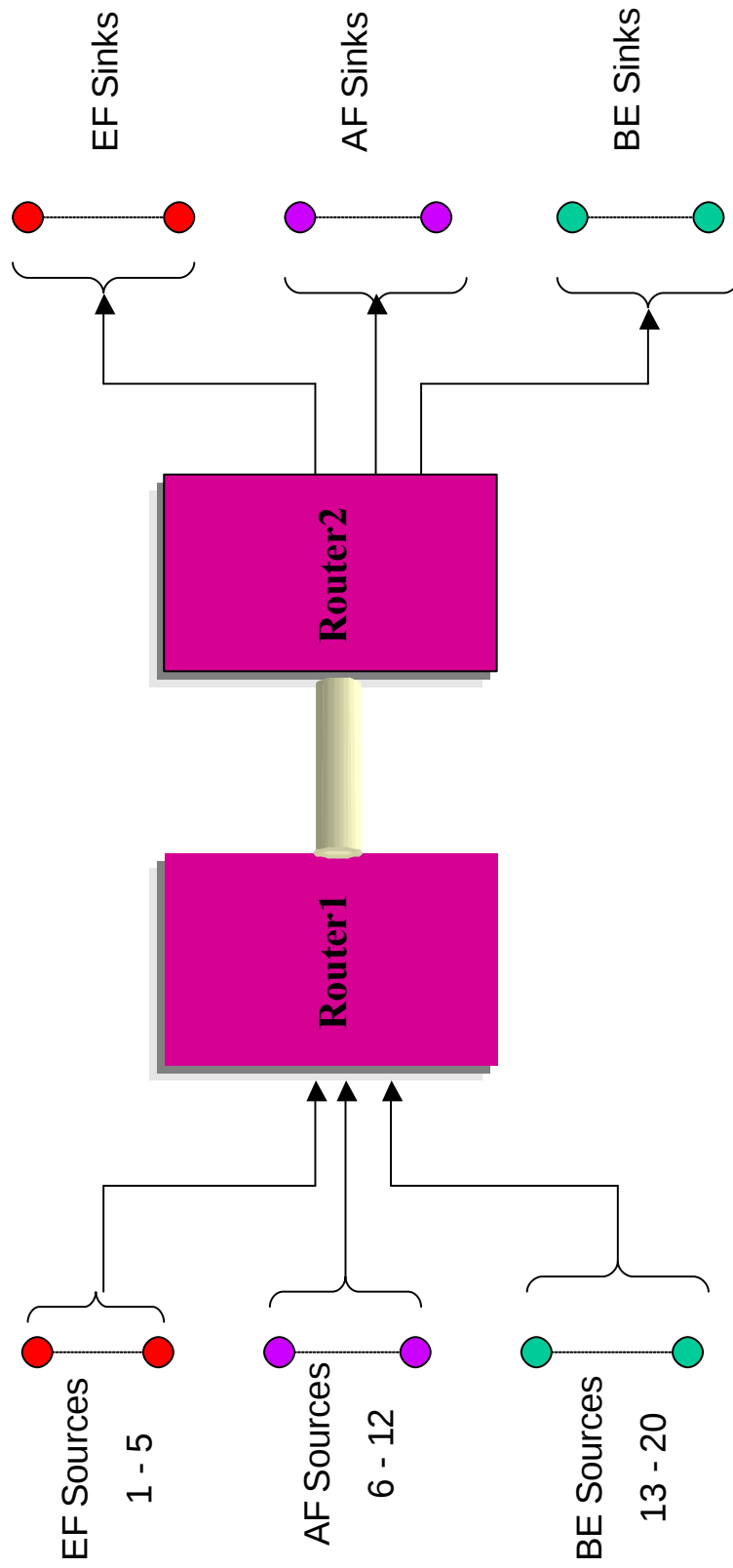
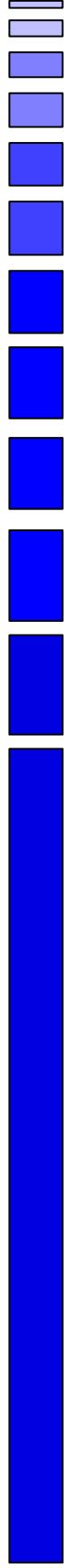
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Mapping of IS to DS (contd.)

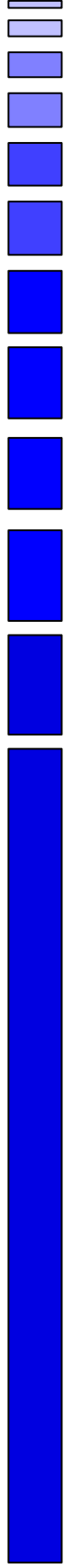


- Packets are forwarded in the DS domain according to the DSCP value and the PHB group.
- The forwarding treatment is basically concerned with the queue management policy and the priority of bandwidth allocation; these ensure the required minimum queuing delay, low jitter and maximum throughput.
- Depending on the implementations of the PHB's inside the network, queue management could be RED, WRED, PQ, WFQ.

IS-DS Simulation Configuration



Task 3



Interoperability with Aeronautical Telecommunications Networks (ATN)

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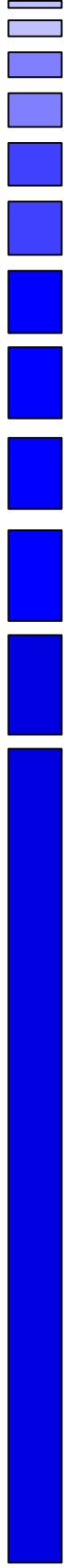
Overview of ATN



- **Aeronautical Telecommunications Network.**
- **Supporting data link based ATC application & AOC.**
- **Integrating Air/Ground & Ground/Ground data communications network into a global internet serving ATC & AOC.**
- **Introducing a new paradigm of ATC based on data link rather than voice communications.**
- **Operating in a different environment with different data communication service provider.**
- **Supporting the interconnection of Ess & Iss using a variety of subnetwork types.**

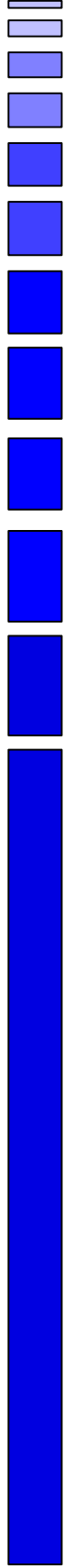
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Purpose of ATN



- Using the existing infrastructure.
- High availability.
- Mobile Communications.
- Prioritized end-to-end resource management.
- Scalability.
- Policy based routing.
- Future proofing

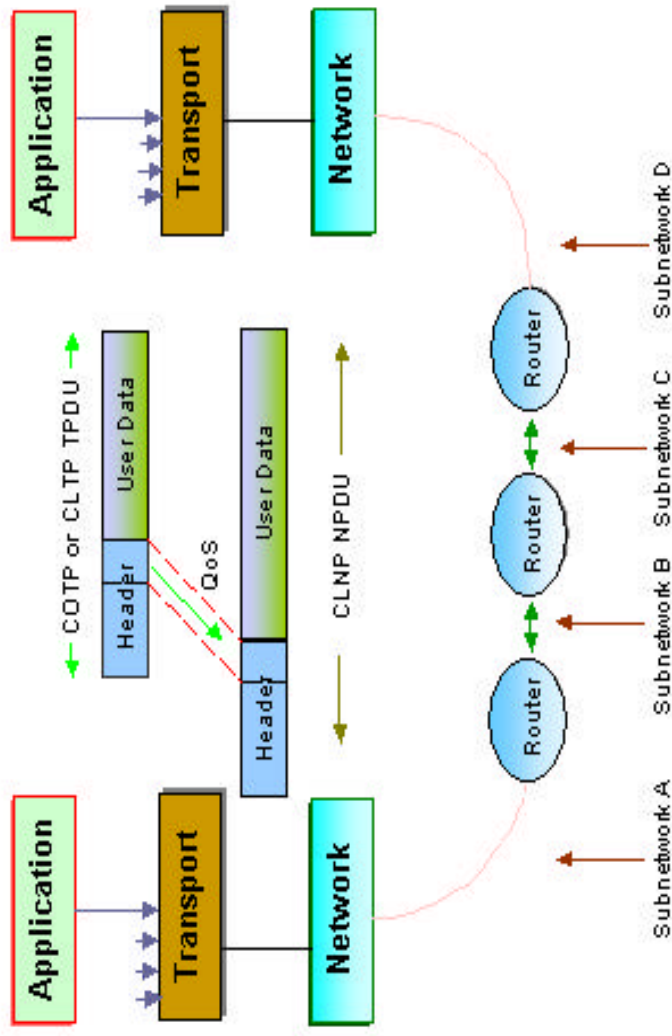
QoS of ATN



- Priority
- Transit Delay
- Error Probability
- Cost
- Security
- Reliability

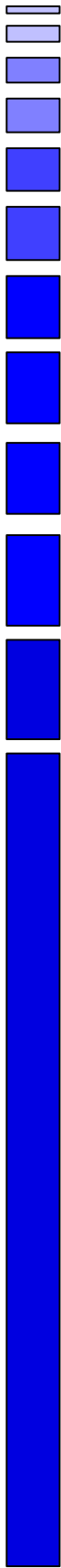
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Model of Transport Layer



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Structure of TPDU



Octet	1	2	3,4	5,6	7	8	p	p+1	z
Length Indicator Field		CR CDT		DST REF	SRC REF	Class Option	TSAP-ID (Source & Destination Address), TPDU size, Preferred max ^m . TPDU size, Version number, Security, Checksum, Additional option selection, Alternative protocol class (es), Acknowledge time, Throughput, Residual error rate, Priority, Transit Delay, Reassignment time & Inactive timer		
Data									

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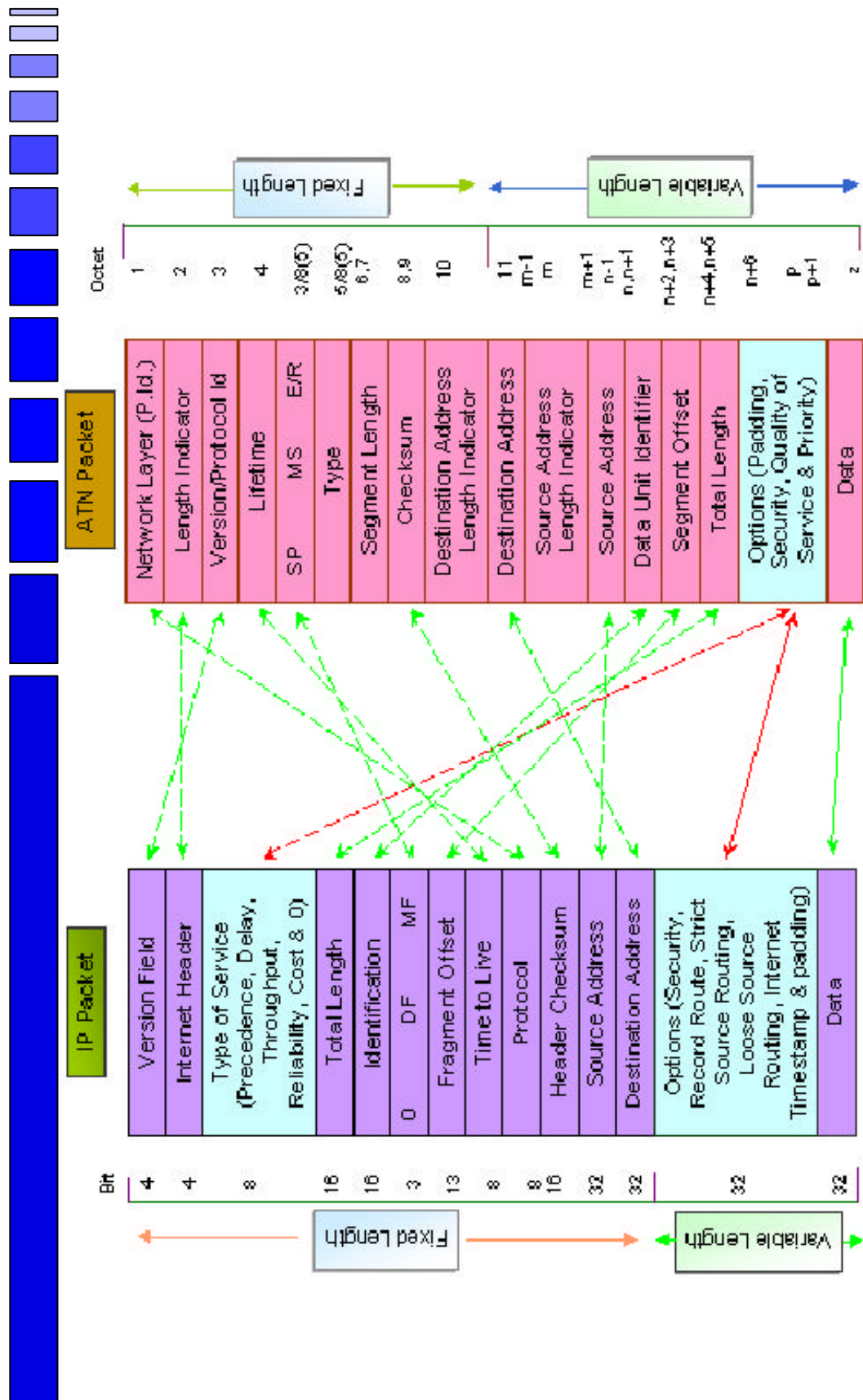
Variable Fields of TPDU header



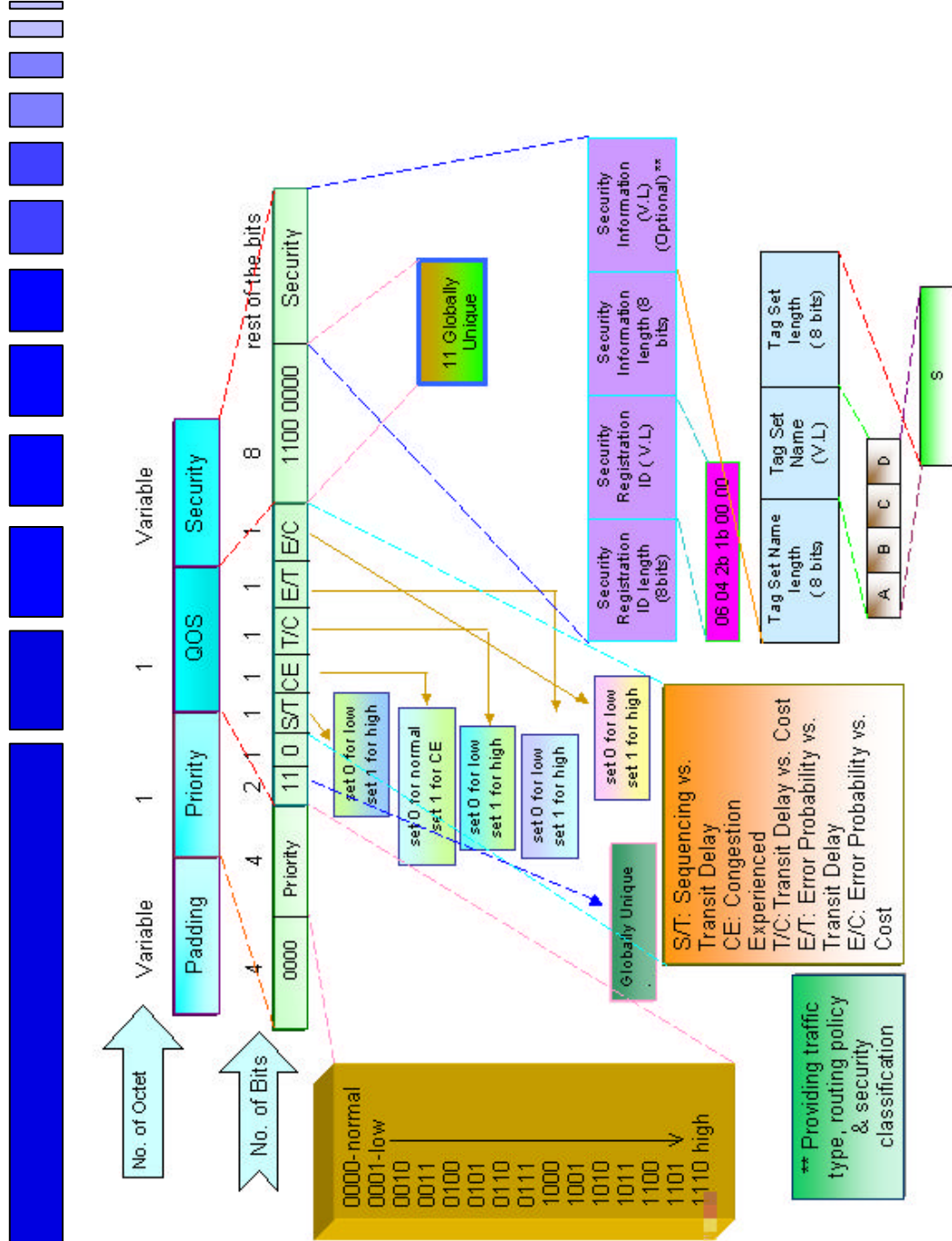
	No. of Octets
TSAP-ID (Source & Destination Address)	Variable
TPDU size	1
Preferred max ^m . TPDU size	up to 4
Version number	1
Security	variable
Checksum	
Additional option selection	1
Alternative protocol class(es)	variable
Acknowledgement time	2
Throughput	12 Or 24
Residual error rate	3
Priority	2
Transit Delay	8
Reassignment time	2
Inactivity timer	4
Data	variable

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Comparison of ATN & IP Packets

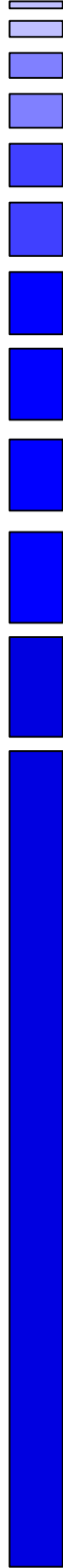


Options Field of ATN Packet





TPDU & NPDU Priority Translation



Message Categories	Transport layer Priority	Network layer Priority
Network/System Management	0	14
Distress Communications	1	13
Urgent Communications	2	12
High priority Flight safety Message	3	11
Normal priority Flight safety Message	4	10
Meteorological Communications	5	9
Flight Regularity Communications	6	8
Aeronautical Information Service Message	7	7
Network/System Administration	8	6
Aeronautical Administrative Messages	9	5
<unassigned>	10	4
Urgent Priority Administration & U.N. Charter Communications	11	3
High Priority Administrative & State/Government Communications	12	2
Normal Priority Administrative	13	1
Low Priority Administrative	14	0

Priorities above the bold line are for the communications related to safety & regularity of flight

Conclusions



- **Tasks are progressing well and as planned.**
- **Modeling of Prioritized EPD has been completed.**
- **OPNET simulation of Prioritized EPD to be continued.**
- **ns simulation of IS over DS to be continued.**
- **ATN over DS mapping to be started.**